AN EXPERIMENTAL STUDY ON THE EFFECTS OF REPEATED HEATING EVENTS ON A CAI BULK COMPOSITION. J. M. Paque[1], L. Le[2], G. Lofgren[3], [1]SETI Institute, NASA-Ames Research Center, M. S. 245-3, Moffett Field, CA 94035-1000, julie@paque.org, [2]Lockheed-Martin, 2400 NASA Road 1, Houston, TX, 77058, loanle@snmail.jsc.nasa.gov, [3]SN-4, NASA-JSC, Houston, TX, 77058, lofgren@snmail.jsc.nasa.gov.

The formation of chondrules and Ca-Al-rich inclusions (CAIs) probably involved more than one sequence of heating and cooling [1-3]. Although the most recent and/or highest temperature event prior to incorporation into the parent body is likely to dominate the texture and chemistry of the object, it is instructive to determine if prior events affect the final product. Information on the nature of the heating/cooling cycles experienced by CAIs and chondrules is important in modeling the environment of their formation.

We have performed a series of experiments on a CAI analog that indicate that the prior history of an inclusion will affect the texture and chemistry of phases formed in subsequent heating events. Both a higher temperature prehistory and a lower temperature prehistory are compared with no pretreatment.

Experimental Techniques. The starting material is the "CAI" bulk composition [4], reflecting the composition of an average Type B CAI. Under isothermal conditions spinel (SP) is the liquidus phase at 1550°C, followed by melilite (MEL; 1400°C), anorthite (AN; 1260°C), and Ti-fassaite pyroxene (TPX; 1230°C). The starting material was prepared as previously described [4], yielding a finely ground glass powder which was attached to a platinum hanging wire with polyvinyl alcohol. A duplicate set of samples with the addition of Pt powder (<3 µm in size) to the starting material was run concurrently. The experiments were carried out in air in a vertical tube Deltech furnace. Cooling rates were controlled with a Eurotherm programmer and samples were quenched in air.

Three types of experiments were performed for each set of run conditions. Figure 1 shows a schematic of the temperature path followed for each type of experiments. The cooling rate for the final stage of the experiments was 20°C/hr and time at T_{max}=0 min, with T_{max}=1420°C. 1450°C, and 1500°C.

1. No pretreatment. The furnace was brought to the run temperature (T_{max}), two samples were inserted (one with Pt and one without), the cooling sequence started immediately (time at T_{max}=0), followed by quenching in air to <1000°C.

2. Low temperature pre-crystallization. The samples were initially run at T_{max}=1275°C, cooling rate (CR)=20°C/hr to <1000°C and removed from the furnace. These conditions had previously been shown to crystallize anorthite reproducibly [5]. The furnace was brought to the run temperature for the second stage of the experiment and the samples reintroduced into the furnace.

3. High temperature pre-crystallization. The samples were initially run at T_{max}=1540°C, CR=200°C/hr to <1000°C and removed from the furnace. These run conditions will crystallize dendritic melilite, a texture not found in natural CAIs. The second stage was performed in the same manner as the low temperature pre-crystallization experiments.

Results. Both high temperature pre-crystallization and low temperature pre-crystallization produced significant variations in the final run product compared to the experiments that underwent no pretreatment. The presence of Pt powder had no significant difference on the texture or chemistry.

Table 1 summarizes the textures of melilite (MEL) and Ti-fassaite pyroxene (TPX) from this series of experiments. Pre-crystallization at high temperature results in more rapid crystal growth forms for both melilite and pyroxene in the final cooling sequence. For example, skeletal or dendritic melilite is present in all experiments that were pre-crystallized at T_{max}=1540°C, compared to euhedral melilite for all experiments with no pretreatment except T_{max}=1500°C.

Low temperature pre-crystallization increases the likelihood of anorthite crystallization in the final cooling sequence. There is very little glass present in the run

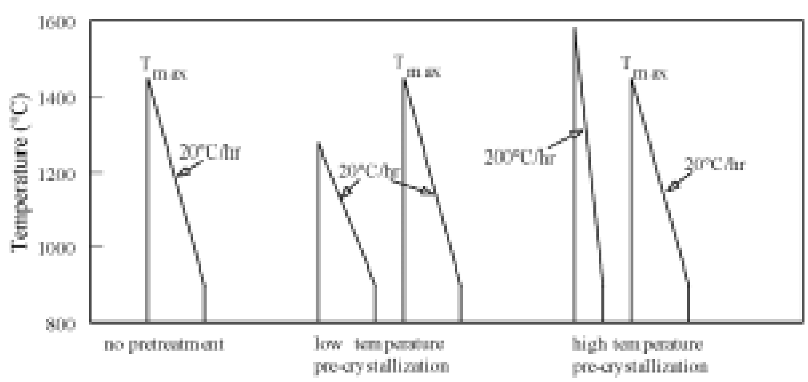

Figure 1. Schematic of the cooling profiles used for cycling experiments. Experiments were done for the following values of T_{max}: 1420°C, 1450°C, and 1500°C. Both the "low temperature pre-crystallization" and "high temperature pre-crystallization" experiments involved two sequences of heating followed by controlled cooling.

Table 1. Comparison of textures produced under various conditions of sample pretreatment.

T_{max}	no pretreatment	low temperature pre-crystallization	high temp. pre-crystallization
1420°C	MEL=euhedral, TPX=euhedral	MEL=euhedral, TPX=euhedral, anorthite present	MEL=skeletal, TPX=skeletal
1450°C	MEL=euhedral, TPX=euhedral	MEL=euhedral/skeletal, TPX=euhedral	MEL=skeletal, TPX=dendritic/skeletal
1500°C	MEL=dendritic, skeletal, TPX=skeletal, euhedral	MEL=euhedral/skeletal, TPX=euhedral, anorthite present	MEL=dendritic, TPX=skeletal

product, and it is much higher in Al_2O_3 and lower in CaO than glass analyzed from experiments with no pre-treatment or high temperature pre-crystallization (Figure 2). This variation in glass composition is independent of the T_{max} of the final heating event.

The trend of the residual liquid suggests that a higher amount of melilite and/or pyroxene crystallized from the experiments with low temperature pre-crystallization. This may be a reflection of the additional nuclei retained in the sample during the second heating event. The initial low temperature crystallization event would have produced a fine grained (5-20 µm) starting material consisting of spinel, melilite, pyroxene, and anorthite. This contrasts with the ground glass starting material used for the experiments that received no pretreatment.

Discussion and Summary. Evidence of previous higher temperature events was retained in the experiments in the form of melilite textures indicative of rapid crystallization. The absence of dendritic melilite in any natural CAIs suggests that they never experienced conditions conducive to the destruction of the majority of the melilite nuclei in the inclusion. Either the temperature was buffered low enough to retain nuclei, or an external source of suitable nuclei for melilite was available. The Pt bearing experiments suggest that Pt metal nuggets do not provide sufficient nucleation sites for melilite.

Samples from experiments with low temperature pre-crystallization prior to the final event are more completely crystallized than those without the prior low temperature history. Repeated cycling of CAIs at temperatures lower than the isothermal crystallization temperature of melilite increases the likelihood of anorthite crystallization at 20°C/hr compared to no pretreatment. Further experiments at more rapid cooling rates will determine the impact of cycling on the range of conditions that will reproduce the mineralogy, textures, and chemistry of natural CAIs.

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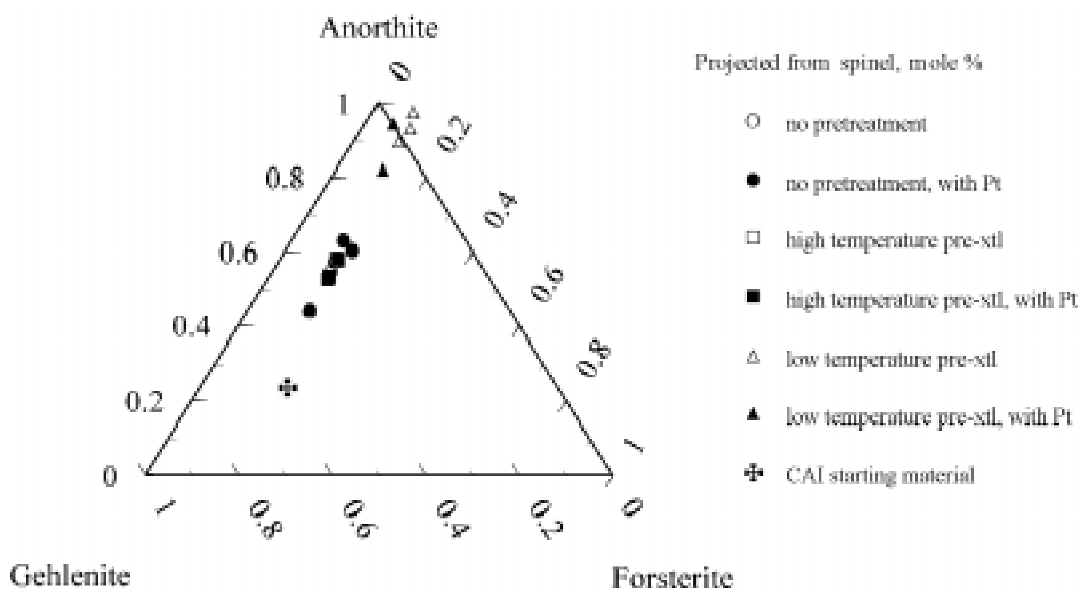

Figure 2. Residual liquid compositions are similar for experiments with no pretreatment (circles) and high temperature pre-crystallization (squares). Samples crystallized at lower temperatures prior to the final heating event produced residual liquid compositions that are enriched in the anorthite component (triangles). Each point represents an average of 2 to 8 glass analyses from a single run product.